Center Innovation Fund: ARC CIF

A New Approach to Uncertainty Reduction in Launch Vehicle Compartment Venting

Completed Technology Project (2012 - 2013)

Project Introduction

Launch vehicle compartments are vented to the external environment during ascent to minimize undesirable structural loading. Prediction of venting performance is an essential element of launch vehicle design and mission development. However, because of complex interactions between the vent flow and the high-speed external flow, there is substantial uncertainty in those predictions. This limitation results in unnecessary vehicle structural mass (reducing payload mass) and increased risk of vehicle or payload loss or damage from structural failure or malfunction. The focus of this project is a novel vent concept offering more predictable performance.

Launch vehicle compartments (e.g. interstage, fairings, payload shroud, etc.) are vented to the external flow during ascent to relieve the internal pressure as the external pressure falls. Vents are openings between the internal compartment and the external environment. They can range in configuration from simple "holes" (orifices) in the vehicle skin to substantially more complicated arrangements. The objectives of the venting system are to minimize adverse differential-pressure loading of the vehicle skin, prevent ingestion of hot gas from the external boundary-layer, and control the compartment depressurization rate to avoid payload damage and ensure proper shroud separation. These requirements are often conflicting, creating a complex design situation where too much venting can be worse than too little.

A transient venting analysis is conducted during vehicle development to determine suitable vent sizes & locations and the resulting structural loads. The present state of the art in venting analysis and design is based on a legacy capability (developed during the late 1960s and early 1970s) that is less than ideal. One known deficiency is that the level of uncertainty in the prediction of vent performance is significant. This uncertainty has costs associated with it. One is that the vehicle structure is over-conservative to account for uncertainty in the predicted skin loads, resulting in an unnecessary reduction in payload capacity. Another cost is the increased risk of damage or malfunction that compromises mission objectives (e.g. 1973 Saturn-V/Skylab-1) or catastrophic failure resulting in vehicle/payload loss. During the 1990s, there was a series of Long March shroud separation failures that were attributed to venting. Recent unexplained shroud separation failures may also be venting related.

While the prediction of launch vehicle compartment venting involves a number of inputs, and corresponding sources of uncertainty, it depends to a large extent on the precision with which the flow characteristics of the vents are known. Unfortunately, the fluid mechanics of a vent discharging into a high-speed cross-flow is extremely complex and not well understood. Consequently, the prediction of vent performance relies on empirically derived discharge coefficients. Such data for compressible cross-flow conditions are extremely limited. Moreover, these data exhibit large variations in measured cross-flow discharge coefficient for supposedly identical test conditions. The

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inconsistencies may be due to unsteadiness, hysteresis, bi-stable phenomena, and/or experimental error. The deficiencies in the available data are presently handled by setting upper and lower limits to bound the observed vent flow characteristics. However, those limits differ by a factor of five in some cases. Another problem is that the experimental data are restricted to idealized vent geometries (i.e. a sharp-edged orifice in a thin plate). How well these data represent the performance of real flight-configuration vents (which can include ducting pathways, screens, rain shields, one-way valves, etc.) is an open question.

The focus of this project is a novel vent concept offering more predictable performance.

Anticipated Benefits

This vent design is favored for use on the Launch Vehicle Stage Adapter compartment of the Space Launch System. It may be used on other SLS compartments (e.g. payload shroud).

This design is being considered as a candidate NASA standard vent for use on a wide variety of launch vehicles.

All of the potential benefits to NASA and DOD would equally applicable to the commercial space industry. Considering its potentially high benefit/cost ratio, this technology would likely be adopted by industry, once developed and proven by the Government.

Department of Defense launches would benefit from a more predictable depressurization of the payload shroud to avoid damage to delicate payloads (e.g. reconnaissance satellites) and ensure proper shroud separation.

Organizational Responsibility

Responsible Mission Directorate:

Space Technology Mission Directorate (STMD)

Lead Center / Facility:

Ames Research Center (ARC)

Responsible Program:

Center Innovation Fund: ARC CIF

Project Management

Program Director:

Michael R Lapointe

Program Manager:

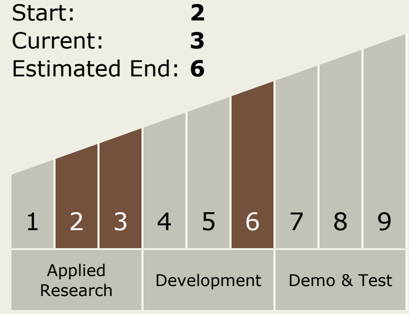
Harry Partridge

Principal Investigators:

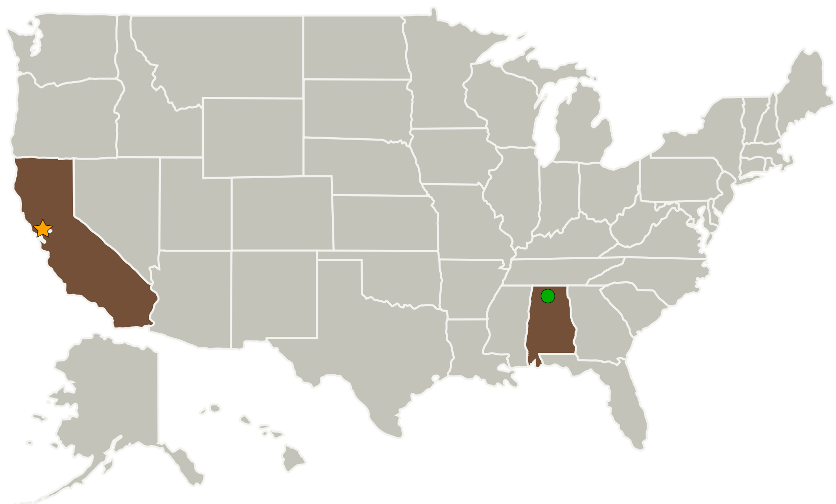
Lawrence A Hand
Blair G Mclachlan

Technology Maturity (TRL)

Start: **2**
Current: **3**
Estimated End: **6**



Primary U.S. Work Locations and Key Partners



Organizations Performing Work	Role	Type	Location
★Ames Research Center(ARC)	Lead Organization	NASA Center	Moffett Field, California
●Marshall Space Flight Center(MSFC)	Supporting Organization	NASA Center	Huntsville, Alabama

Primary U.S. Work Locations	
Alabama	California

Stories

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(https://techport.nasa.gov/file/8757)

Technology Areas

Primary:

- TX15 Flight Vehicle Systems
  - └ TX15.2 Flight Mechanics
    - └ TX15.2.2 Flight Performance and Analysis